What's My Pavement Worth?

FAA Airport Technology Transfer Conference

April 2010

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Basis of Research Results

- AAPTP Project 06-07, *Assessment of FAA HMA Overlay Procedures*
- Expected completion date: April 2010

Project Team

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- Genevieve Long, APTech
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- Rajib Mallick, Worcester Polytechnic Institute

Technical Panel

- Monte Symons, AAPTP
- Rich Thuma, CMT
- Ray Brown, Auburn University
- David Brill, FAA
- Guy Zummo, PANYNJ
- Linbing Wang, Virginia Tech

Introduction

- New FAA Advisory Circular for new pavement and overlay design (150/5320-6E)
- Mechanistic-empirical approach
- SCI used to characterize existing PCC for overlays
- To characterize existing HMA pavements:
  - No approach outlined
  - Very little guidance included

Project Objectives

- Review FAA and other available HMA overlay design procedures
- Develop guidelines for characterizing existing pavement, including application of corrective actions, for establishing design inputs
- Identify potential improvements in FAA HMA overlay design procedure

Project Activities

1. Review available design procedures
2. Perform FAARFIELD sensitivity analysis
3. Review existing pavement evaluation methods
4. Summarize corrective repair actions
5. Develop guidelines for FAA HMA overlay design using FAARFIELD
6. Develop recommendations for revisions and improvements

Review of Available Design Procedures and Performance Models

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Design Procedures

- Primarily based on empirical relationships initially developed 60 years ago
- Established procedures generally consider *subgrade rutting* and *HMA fatigue*
- Required overlay thickness determined by structural deficiency of existing pavement

Commonly Available Procedures

- FAA
  - 5320-6D – nomograph
  - 5320-6D (change 3) – LEDFAA
  - 5320-6E – FAARFIELD
- Military – PCASE
  - CBR-based
  - Layered elastic
- Asphalt Institute (AI)

Pavement Responses

- Rutting
  - Permanent deformation of subgrade (vertical strain at top of subgrade)
  - Assume no deformation of bound or granular layers
- HMA fatigue
  - Horizontal strain at bottom of surface layer
  - Horizontal strain at bottom of bound layers

FAA AC 150/5320-6D

- CBR-based method
- Traffic characterized by “design aircraft”
- Uses design nomographs (later incorporated into spreadsheet)
- Layers characterized using equivalency factors

FAA AC 150/5320-6E

- Mechanistic-empirical design
- Uses layered elastic theory (LEAF) to determine pavement responses
- Employs CDF concept (models still calibrated to CBR method)
- Input full traffic mix
- Layers characterized using elastic modulus and Poisson’s ratio
- Uses FAARFIELD program

FAARFIELD Performance Models

- FAARFIELD
  - Subgrade Rutting:

$$C = \left(\frac{0.004}{\varepsilon_v}\right)^{8.1} \qquad \text{when } C \le 12{,}100$$

$$C = \left(\frac{0.002428}{\varepsilon_v}\right)^{14.21} \qquad \text{when } C > 12{,}100$$

  - HMA Fatigue:

$$\log_{10}(C) = 2.68 - 5 * \log_{10}(\varepsilon_h) - 2.665 * \log_{10}(E_A)$$

Characterization of Existing Materials

- Elastic modulus is fixed for standard materials:
  - HMA surface: 200,000 psi
  - HMA base: 400,000 psi
- Can use “variable” or “undefined” layer to input different modulus
- Poisson’s Ratio = 0.35

Modeling of Existing Pavement

- Layers are assumed to be bonded
- Fatigue cracking is not default failure criterion (but can be turned on by user)
- Evaluates tensile strain at bottom of HMA surface layer only
- Does not account for any damage in the existing pavement

Military Pavement Design

- Defined in UFC 3-260-02
- Incorporates designs for:
  - Army
  - Navy
  - Air Force
- Two approaches:
  - CBR method
  - Layered elastic method
- Incorporated into PCASE program

PCASE Performance Models

- PCASE (layered elastic)
  - Subgrade Rutting:

$$C = 10{,}000\left(\frac{0.000247 + 0.000245.\log_{10}(E_{SG})}{\varepsilon_v}\right)^{0.0658 E_{SG}^{\,0.559}}$$

  - HMA Fatigue:

$$N = 10^{2.68 - 5.0\log(S_A) - 2.665\log(E)}$$

Highlights of Military Pavement Design

- Approach similar to FAA
- Looks at fatigue at bottom of stabilized layer(s)
- Not much guidance on selecting properties of existing layers
- Allows evaluation using different seasons

Asphalt Institute (AI) Procedure

- Two limiting design criteria
  - Compressive strain on subgrade
  - Tensile strain at bottom of HMA layer
- Mean annual air temperature used to account for effect on HMA performance

AI Conversion Factors

CONVERSION FACTORS FOR CONVERTING THICKNESS OF EXISTING PAVEMENT COMPONENTS TO EFFECTIVE THICKNESS (T_e)
(These conversion factors apply ONLY to pavement evaluation for overlay design. In no case are they applicable to original thickness design.)

Classification of Material	Description of Material	Conversion Factors*
I	a) Native subgrade in all cases	0.0
	b) Improved Subgrade**—predominantly granular materials—may contain some silt and clay but have P.I. of 10 or less	
	c) Lime modified subgrade constructed from high plasticity soils—P.I. greater than 10.	
II	Granular Subbase or Base—Reasonably well-graded, hard aggregates with some plastic fines and CBR not less than 20. Use upper part of range if P.I. is 6 or less; lower part of range if P.I. is more than 6.	0.1-0.2
III	Cement or lime-fly ash stabilized subbases and bases** constructed from low plasticity soils—P.I. of 10 or less.	0.2-0.3
IV	a) Emulsified or cutback asphalt surfaces and bases that show extensive cracking, considerable raveling or aggregate degradation, appreciable deformation in the wheel paths, and lack of stability.	0.3-0.5
	b) Portland cement concrete pavements, (including those under asphalt surfaces) that have been broken into small pieces 0.6 metre (2 ft) or less in maximum dimension, prior to overlay construction. Use upper part of range when subbase is present; lower part of range when slab is on subgrade.	
	c) Cement or lime-fly ash stabilized bases** that have developed pattern cracking, as shown by reflected surface cracks. Use upper part of range when cracks are narrow and tight; lower part of range with wide cracks, pumping or evidence of instability.	
V	a) Asphalt concrete surface and base that exhibit appreciable cracking and crack patterns.	0.5-0.7
	b) Emulsified or cutback asphalt surface and bases that exhibit some fine cracking, some raveling or aggregate degradation, and slight deformation in the wheel paths but remain stable.	
	c) Appreciably cracked and faulted portland cement concrete pavement (including such under asphalt surfaces) that cannot be effectively undersealed. Slab fragments, ranging in size from approximately one to four square metres (yards), and have been well-seated on the subgrade by heavy pneumatic-tired rolling.	
VI	a) Asphalt concrete surfaces and bases that exhibit some fine cracking, have small intermittent cracking patterns and slight deformation in the wheel paths but remain stable.	0.7-0.9
	b) Emulsified or cutback asphalt surface and bases that are stable, generally uncracked, show no bleeding, and exhibit little deformation in the wheel paths.	
	c) Portland cement concrete pavements (including such under asphalt surfaces) that are stable and undersealed, have some cracking but contain no pieces smaller than about one square metre (yard).	
VII	a) Asphalt concrete, including asphalt concrete base, generally uncracked, and with little deformation in the wheel paths.	0.9-1.0
	b) Portland cement concrete pavement that is stable, undersealed and generally uncracked.	
	c) Portland cement concrete base, under asphalt surface, that is stable, non-pumping and exhibits little reflected surface cracking.	

*Values and ranges of Conversion Factors are multiplying factors for conversion of thickness of existing structural layers to equivalent thickness of asphalt concrete.
**Originally meeting minimum strengths and compaction requirements.

Other Failure Modes to Consider

- Permanent deformation
  - HMA deformation
  - Granular layer deformation
- Thermal cracking
- Reflective cracking
- Top-down cracking
- Delamination

FAARFIELD Sensitivity Analysis

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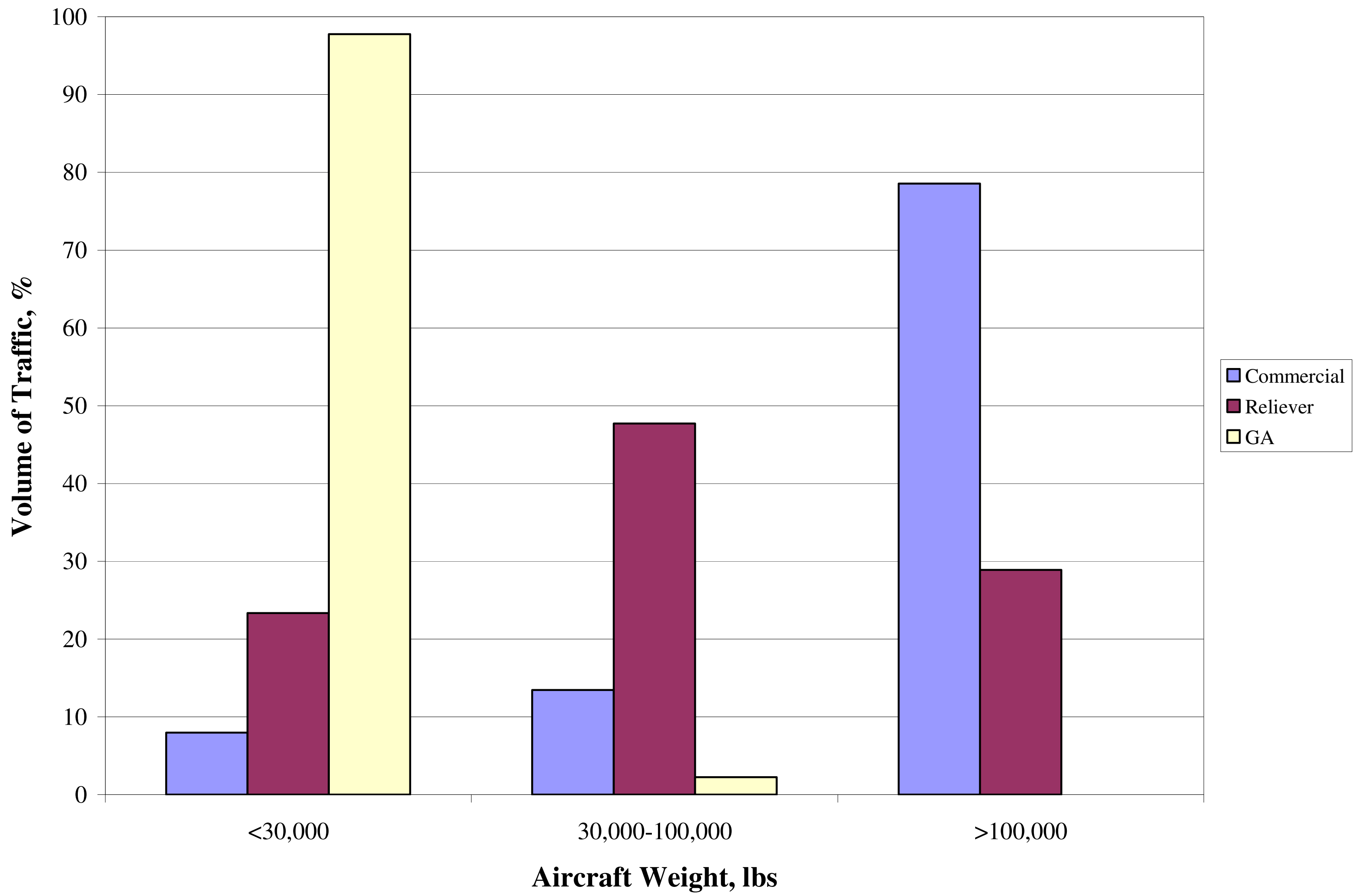
Purpose of Sensitivity Analysis

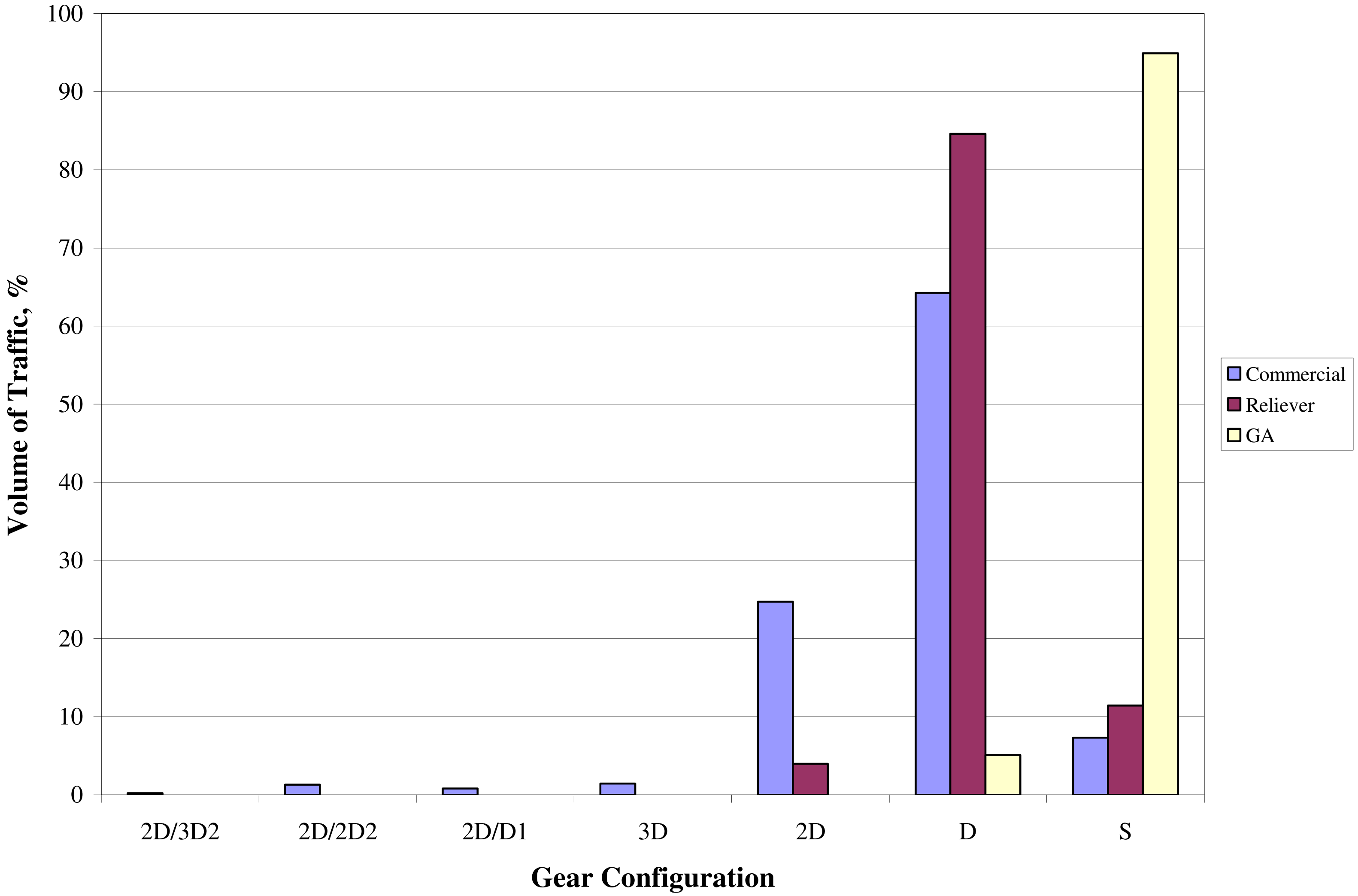
- Evaluate effect of various inputs on resulting overlay thickness
- Investigate impact of potential changes to FAA overlay design

Note: did not have access to code, so only certain inputs could be evaluated.

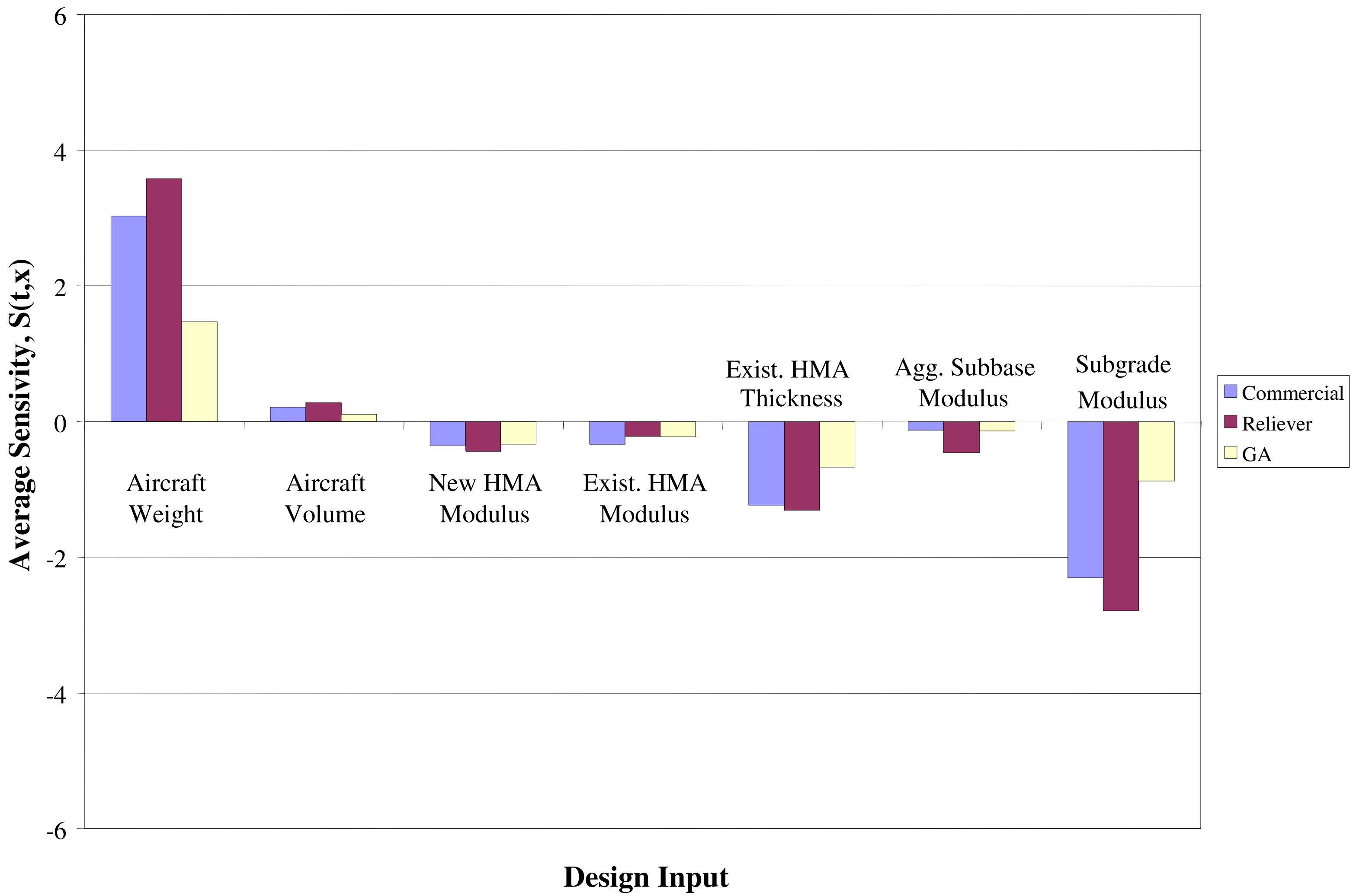
Traffic Mixes (Aircraft Weight Distribution)



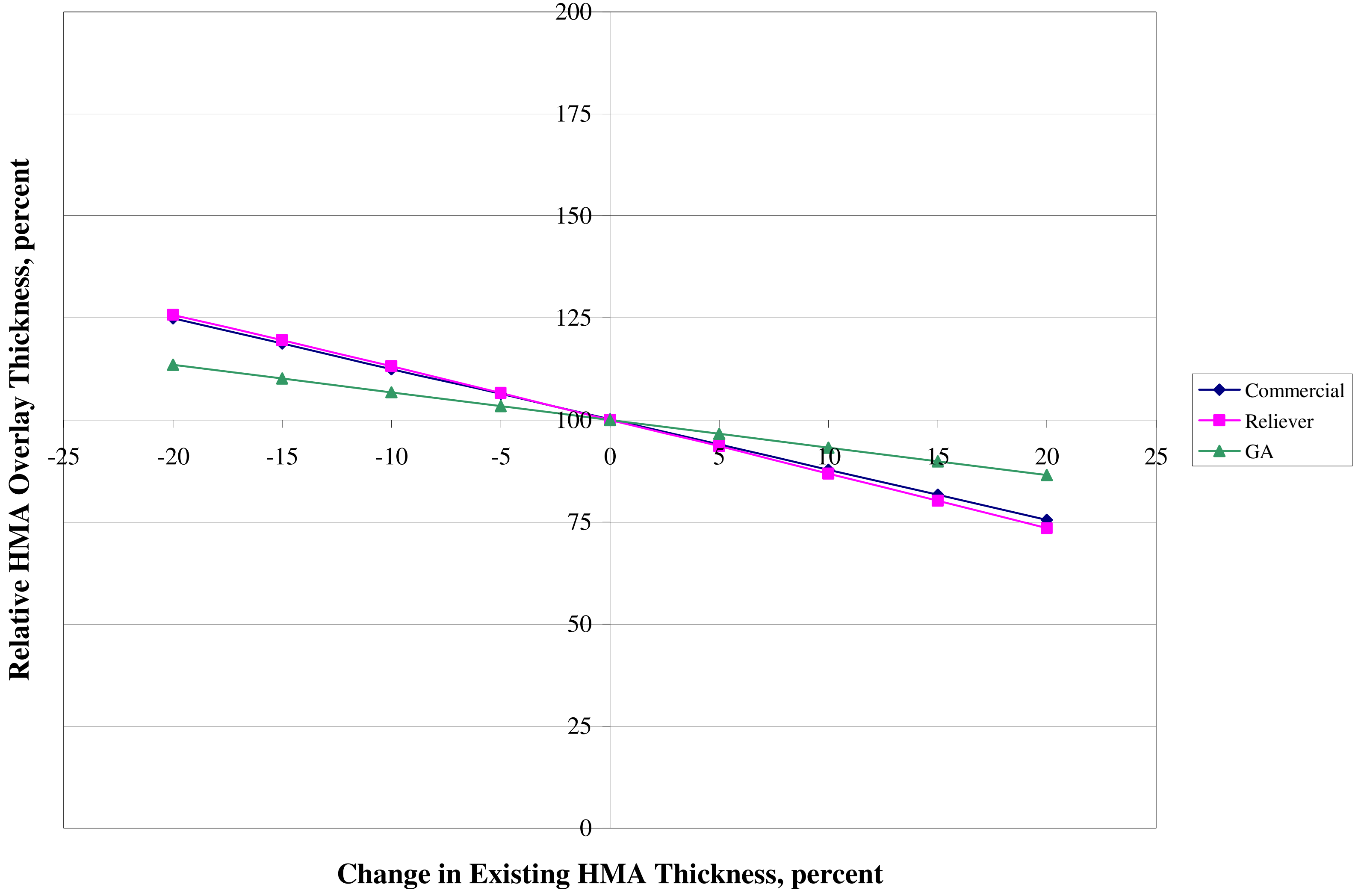
Traffic Mixes (Aircraft Gear Configuration)



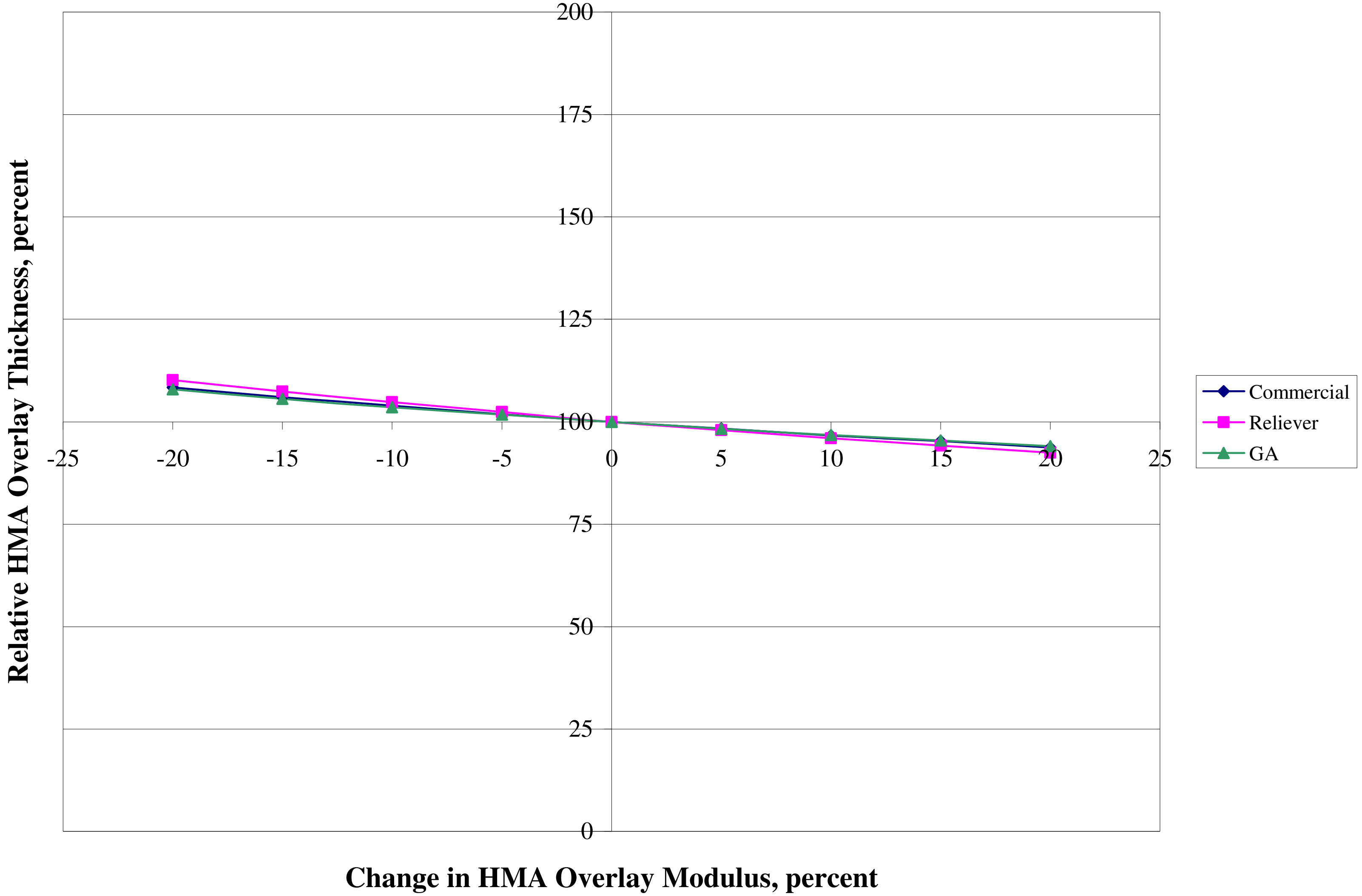
Average Sensitivity of Inputs



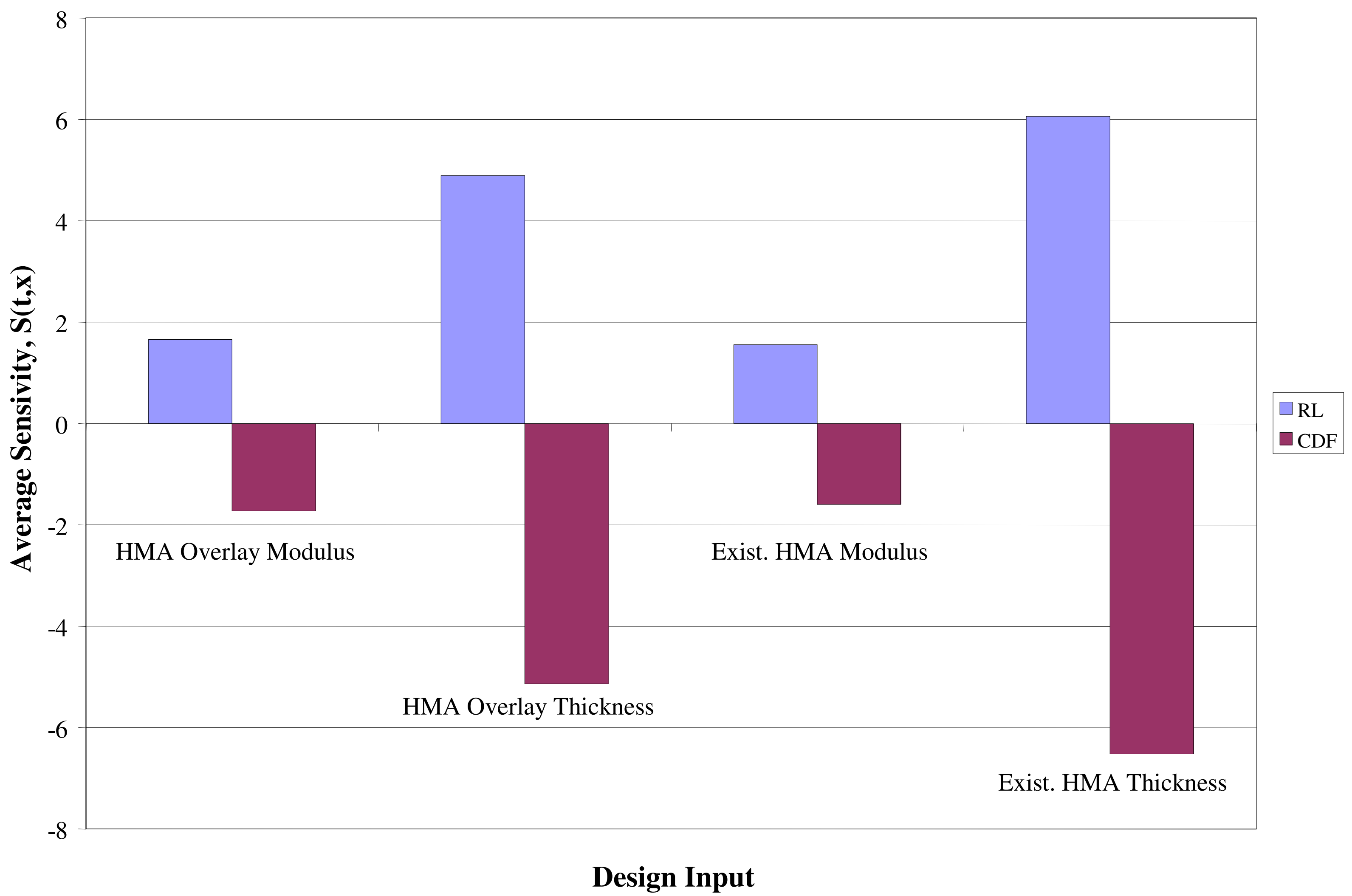
Sensitivity to Existing HMA Thickness



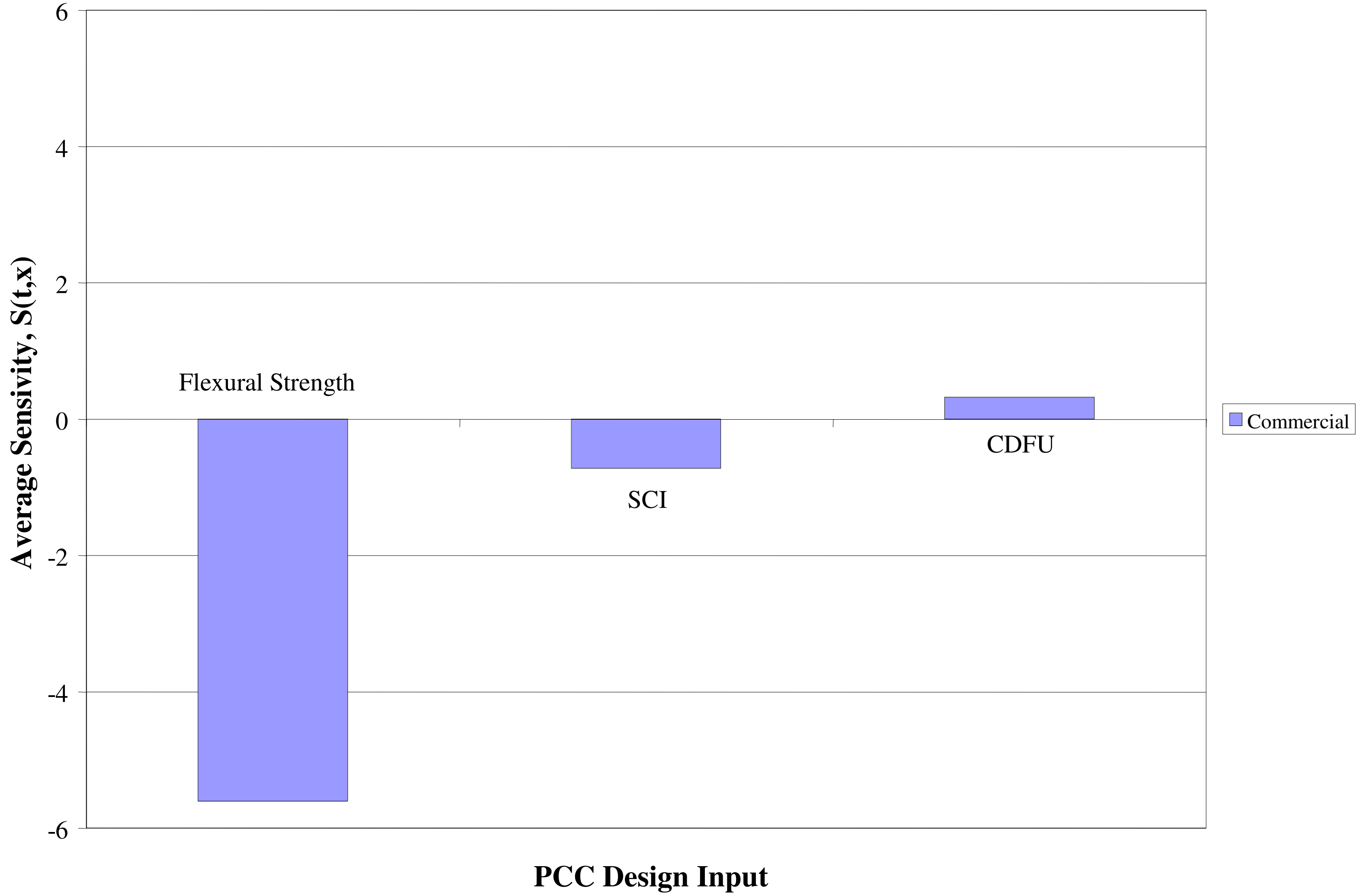
Sensitivity to Existing HMA Modulus



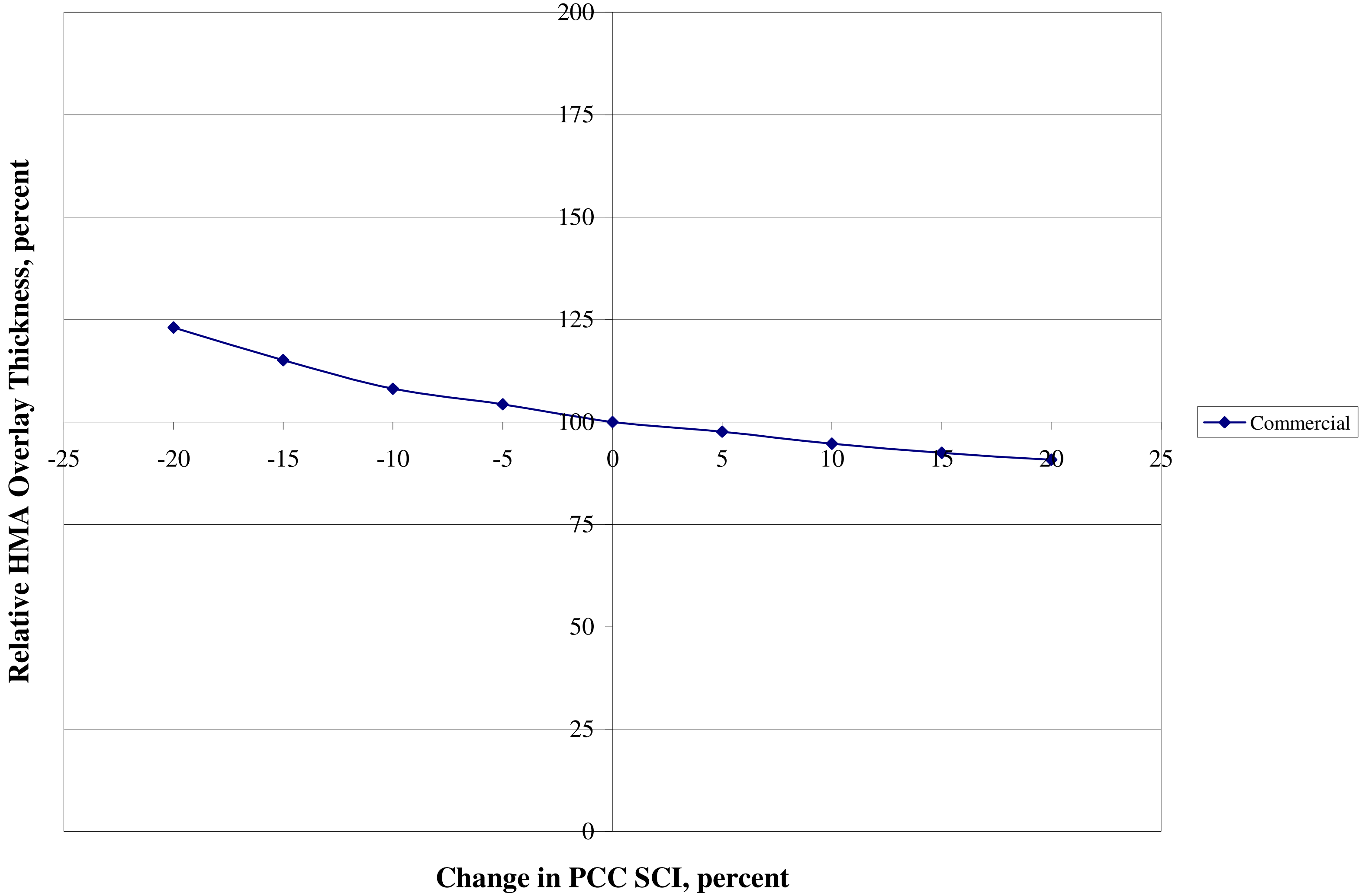
Sensitivity of Remaining Life and CDF



Sensitivity of Inputs for Composite Pavements



Impact of SCI on HMA Overlay Thickness



Typical Modulus Values and Ranges (Stubstad et al. 2006)

Material	Backcalculation		FAARFIELD Input	
	Layer Type	Common Modulus Range, psi[1]	Layer Type	Modulus Range, psi
Flexible surface	HMA (dense-graded) surface	101,500 to 3,625,000	P-401	200,000
PCC surface	PCC surface	1,450,000 to 10,150,000	P-501	4,000,000
Flexible stabilized bases	Asphalt treated base	101,500 to 3,625,000	P-401/P-403 Variable stabilized (flexible)	400,000 250,000 to 700,000
Rigid stabilized bases	Econocrete base Cement treated base Soil Cement	507,500 to 5,075,000 290,000 to 2,900,000 145,000 to 1,015,000	P-306 P-304 P-301 Variable stabilized (rigid)	700,000 500,000 250,000 250,000 to 700,000
Unbound aggregate	Granular (crushed) base Granular (uncrushed) subbase	14,500 to 217,500 7,250 to 108,750	P-209 P-154	75,000[2] 40,000[2]
Undefined	N/A	N/A	Undefined	1,000 to 4,000,000

[1] Stubstad et al. 2006

[2] Initial values; final design values are calculated internally.

Typical Modulus Values and Ranges (FAA 2004)

Material	Backcalculated Value, psi	FAARFIELD Input, psi
Stabilized base/subbase under HMA	> 400,000	400,000
	150,000 to 400,000	Backcalculated value
	< 150,000	150,000
Cement stabilized base/subbase under PCC	> 700,000	700,000
	250,000 to 700,000	Backcalculated value
	< 250,000	250,000
Granular base and subbase	> 40,000	Use P-209
	< 40,000	Use P-154

Conclusions from Sensitivity Analysis

- Need to assess in situ subgrade support conditions
- Adjustment needed if existing HMA modulus differs by more than 10% from default (use undefined layer)
- Modulus of granular layers has minimal impact (current approach okay)

Characterization of Existing Pavement Layers

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Characterization of Existing Pavement Layers

- Visual
  - PCI
  - SCI
- Destructive
  - Coring
  - Subsurface boring
- Non-destructive
  - GPR
  - Deflection
  - Seismic and other

Visual Pavement Assessment

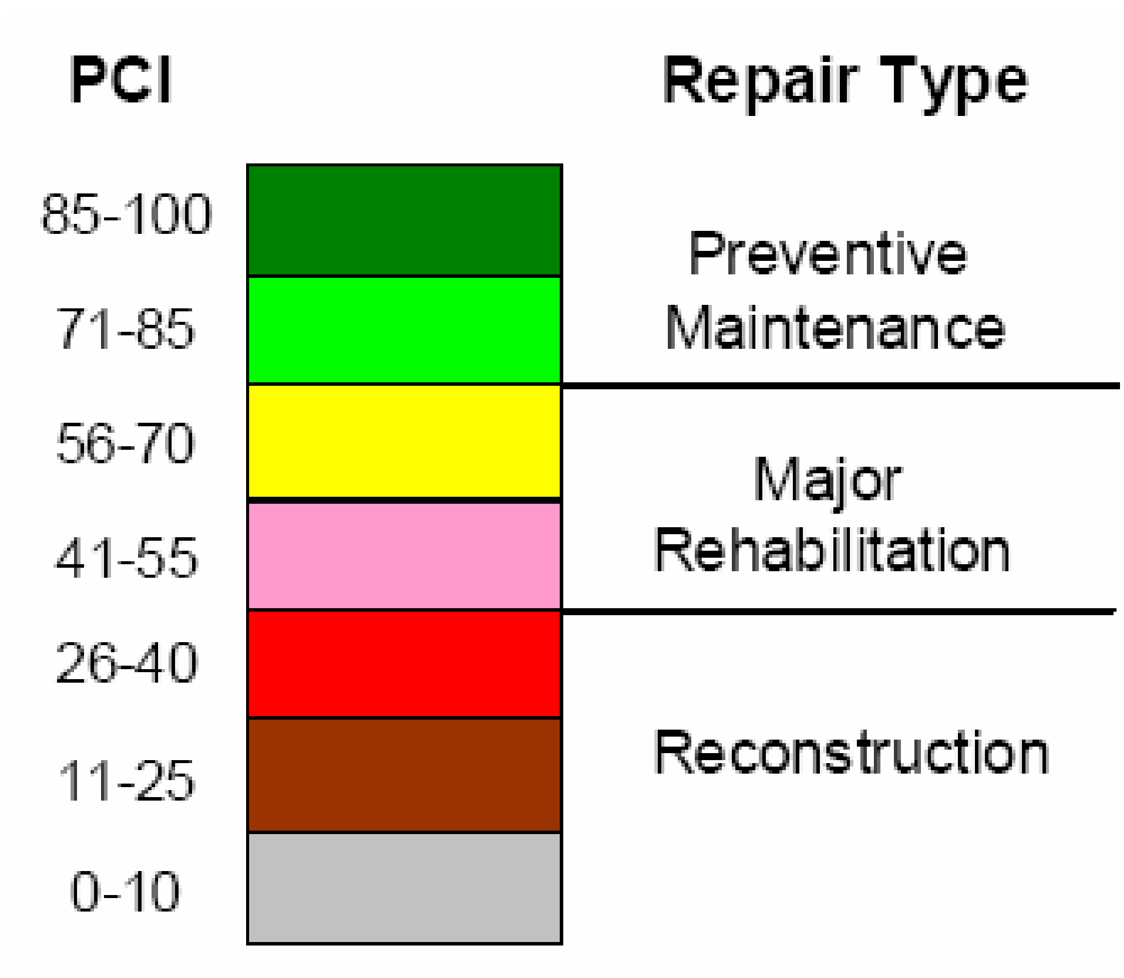
- PCI
  - Surface distresses only
  - Type, severity, and quantity
  - Cause: climate, load, or other
- SCI
  - Subset of PCI data
  - Load-related distresses

$$SCI \geq PCI$$

Causes of Pavement Distress

Pavement Type	Pavement Distress Category		
	Load-Related	Climate-Related	Other
HMA-Surfaced Pavements	• Fatigue (Alligator) Cracking • Rutting	• Block Cracking • Joint Reflection Cracking • Longitudinal and Transverse Cracking • Patching • Raveling and Weathering	• Bleeding • Corrugation • Depression • Jet Blast • Oil Spillage • Polished Aggregate • Shoving • Slippage • Swelling
PCC Pavements	• Corner Break • Linear Cracking • Shattered Slab	• Blow-up • Durability Cracking • Joint Seal Damage	• Small/Large Patch • Popouts • Pumping • Scaling, Map Cracking, and Crazing • Faulting/Settlement • Shrinkage Cracking • Spalling, Joint/Corner

PCI Scale


PCI
Repair Type
85-100
71-85
56-70
41-55
26-40
11-25
0-10
Preventive Maintenance
Major Rehabilitation
Reconstruction

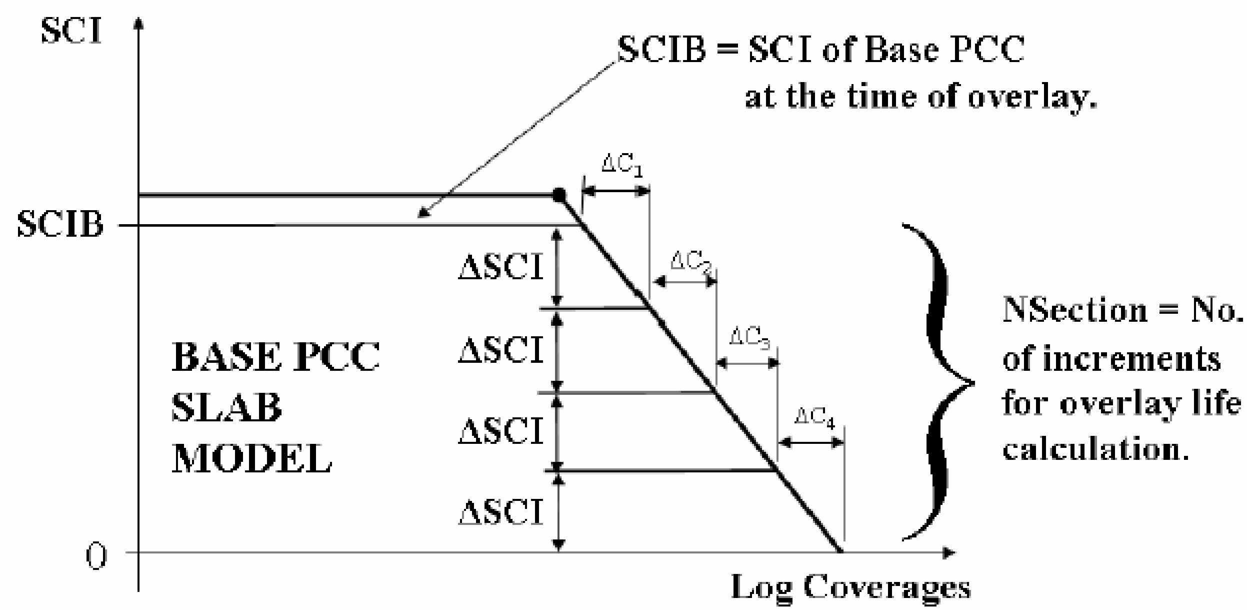
SCI for PCC Pavements

- PCC includes corner breaks, mid-panel cracks, and shattered slabs
- SCI of 80 consistent with 50 percent of slabs with cracking in wheel path
- If SCI data not available, can be estimated:

$$SCI = 100 * C_b - 25$$

SCI for Composite Pavements

- SCI used to model deterioration of PCC modulus over time
- CDFU can be used if failure hasn't yet occurred (SCI = 100)

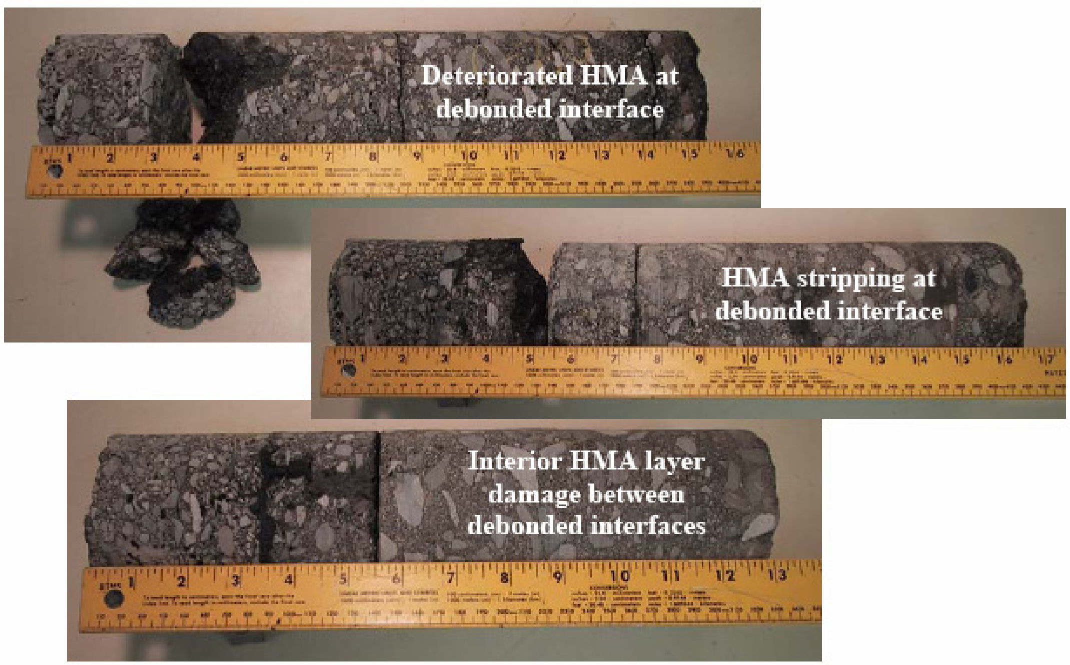


SCI for HMA Pavements

- Not as clearly defined
- Distresses included not generally agreed upon for HMA:
  - FAA – fatigue and rutting
  - COE – fatigue, rutting, depression, L&T cracking, patching (due to included distresses), and slippage cracking
- Possibly multiple causes (rutting caused by material instability and/or subgrade rutting)
- SCI at failure for HMA not clearly defined or accepted

Destructive Testing

- Cores
  - Bound layer thicknesses
  - Relative quality of material/underlying problems: stripping, delamination, and so on



Destructive Testing (cont.)

- Borings
  - Thickness and quality of unbound layers
  - Subgrade characteristics
  - Sample retrieval
- Dynamic Cone Penetrometer
  - Penetration correlated to CBR/modulus
- Other tests
  - In-place CBR and others

Destructive Testing (cont.)

- Laboratory testing of retrieved samples
  - Bound layer testing
    - HMA – Modulus, volumetrics, and so on
    - PCC – Flexural strength, modulus, petrographic, others
  - Granular layer testing
    - CBR/modulus, classification properties
  - Subgrade testing
    - CBR/modulus, classification properties

Nondestructive Testing (NDT)

- Deflection testing (FWD is most common)
  - Overall response to load
  - Layer moduli
  - Localized areas of weakness
- Ground Penetrating Radar
  - Layer thicknesses
  - Possible delamination/stripping detection
- Seismic methods (such as PSPA)
  - Layer modulus
  - Possible delamination/stripping detection

Characterization of Existing Pavement

- Advantages and disadvantages for each technique
- Best to use combination of techniques
- Existing layer thicknesses and moduli can be used as inputs in FAARFIELD; other data (such as stripping, delamination, volumetrics, and so on) are assessed externally

Corrective Actions

- Localized repair – Partial- and full-depth patching
- Surface leveling
  - Cold milling
  - Additional thickness
- Reflection cracking control
  - Crack sealing
  - Geotextile
  - Stress absorbing/relieving interlayer
  - Reinforcement
- Material modification

Preliminary Recommendations

- Design for fatigue cracking at bottom of stabilized layers (not just bottom of surface)
- Adjust existing HMA modulus to account for deterioration
- Evaluate other possible failure modes:
  - Rutting in HMA and unbound layers
  - Reflective cracking
- Allow debonding to analyze existing pavements

Guidelines

- Stand-alone guide for practitioners
- Step-by-step approach to HMA overlay design using FAA procedure
- Topics will include:
  - Overview of HMA overlay design process
  - Selection of design features and inputs
  - Evaluation of existing pavement
  - Effective use of FAARFIELD

Questions?

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